Existing Research found in light literature search:

Literature Search on Comparing the Performance of the WaveLogic Rebel Sensor and the Giatet Smart Rock + Sensor to Predict Early Age and Later Age Concrete Strength

"Real-time monitoring of early-age compressive strength of concrete using an IoT-enabled monitoring system: an investigative study"
Innovative Infrastructure Solutions, 2023
https://link.springer.com/content/pdf/10.1007/s41062-023-01043-7.pdf

Determination of the early-age compressive strength of concrete is essential for quality assurance, safety, and economy of construction projects. Due to manual operation on construction site, conventional maturity meters are not efficient for live monitoring of the early-age concrete strength. Higher levels of automated and computerized improvements have been made possible by recent developments in wireless communications, sensor technologies, and data processing methods across the construction industry. For real-time monitoring of the early-stage concrete strength, the current study presents an innovative Internet of Things (IoT)-enabled system developed by concrete data sensors (CDS), an Australian-owned private business. The CDS sensor system (the system) communicates with temperature sensors via long-range wide-area network and is linked to a cloud-based platform for data storage. The suggested system's effectiveness was assessed using three concrete mixtures and developed maturity relationships. It was observed that the predicted early-age compressive strength of the mixes matches well with the actual compressive strength and that the system can effectively automate the characterization of maturity.

"Non-Destructive Testing for Quality Assurance of Concrete & Performance Prediction of Bridge Decks with Machine Learning"
University of Maryland, 2022
https://www.proquest.com/docview/2776466629?pq-origsite=gscholar&fromopenview=true&sourcetype=Dissertations%20&%20Theses

Non-destructive testing (NDT) methods are particularly valuable in the quality assurance (QA) process since they do not interfere with production of concrete and reduce testing time and cost. NDTs can provide early warnings in meeting strength requirements at early ages of concrete as well as long term strength. NDTs are also valuable in providing evaluation of health of in-service infrastructures such as bridge and pavement.

The results of this study can be used for potential adoption of an NDT-based QA plan. Their adoption in QA will provide the opportunity to test a larger portion of concrete during assessment without a significant increase in QA cost and testing time. To achieve that purpose, the selected NDTs should be fast, accurate, reliable and simple to run. The NDT methods explored in this study included infrared thermography, ultrasonic pulse velocity (UPV), fundamental resonance frequency, rebound hammer, ground penetrating radar (GPR), and ultrasonic pulse echo (UPE).

Different sets of NDTs were selected in each experimental study undertaken in this dissertation appropriate to the research objectives and goals in each case. For strength gain monitoring, (i.e., maturity modeling during early ages of hydration), the suggested NDTs need to provide an assessment of the mechanical properties of concrete. To assess the concrete quality during production and/or construction the selected NDTs should rapidly identify potential issues concerning uniformity and/or the presence of production and placement defects. For evaluating the condition of concrete bridge decks with asphalt overlays, GPR response was used to detect layer thickness and concrete quality and to evaluate reinforcement condition. For addressing the transition from lab to field results, machine learning modeling was used to predict the structure condition. Therefore, two artificial neural network (ANN) models were proposed and assessed in this study to predict the condition of bridge decks in Maryland and Massachusetts.

Thus, the objectives of this research were to identify and assess alternative NDT methods that can be used in: i) monitoring and/or estimating strength gain (i.e., maturity modeling) in concrete; ii) evaluating concrete uniformity and production quality; iii) detecting and measuring the extent of delamination in concrete slab representing small scale field conditions; iv) evaluating GPR in assessing the condition of pavement layers, concrete quality and reinforcement in bridge decks; and v) employing machine learning modeling to predict the condition of bridge decks.

"Concrete strength gain monitoring with non-destructive methods for potential adoption in quality assurance"
Construction and Building Materials, 2020
https://www.sciencedirect.com/science/article/pii/S0950061820324697

During concrete production, simple and quick testing methods are desired for assessing concrete properties. Non-destructive testing methods, NDT, are particularly valuable in the Quality Assurance and Quality Control (QA/QC) process since do not interfere with production of concrete and reduce testing time and cost. Concrete hardening, and thus strength gain, is one of the most important parameters in concrete production since it can immediately identify potential issues in concrete proportioning, curing conditions, and use of questionable ingredients that affect strength and stiffness. NDTs can provide early warnings in meeting strength requirements at early ages as well as long term strength. NDTs are also valuable in providing strength gain predictions so that follow-up construction can continue once the minimum critical strength is achieved. This research was developed based on the recommendations of a recent national study undertaken by the authors for Federal Highway Administration in developing an NDT based QA process for highway materials. Thus, it was the objective of this research to identify and assess alternative NDT methods that can be used in monitoring and/or estimating strength gain in concrete, and thus for potential adoption an NDT based QA plan. These NDTs should be fast, accurate, reliable and simple to run. The NDT methods explored in this study included: infrared thermography, ultrasonic pulse velocity, and fundamental resonance frequency. The results from such testing methods were coupled with maturity modeling for monitoring and predicting concrete strength at early ages. The results provided good relationships with the maturity index. Even though the relationships of these NDT outputs with the maturity index were based on limited set of experimental data, it is expected that their accuracy will improve with complementary testing on additional concrete mixtures. The methodology of this study is applicable elsewhere where similar materials and construction methods are used.

"IoT Enabled Real-Time Monitoring System for Early-Age Compressive Strength of Concrete"

Journal of Construction Engineering and Management, 2019

https://ascelibrary.org/doi/10.1061/%28ASCE%29CO.1943-7862.0001754

The estimation of the early age compressive strength of concrete is crucial for quality control in the construction industry. The present study proposes an innovative and cost-effective Internet of Things (IoT)-enabled system for the real-time monitoring of early age concrete strength. The proposed system consists of temperature sensors and Wi-Fi microcontrollers that are connected to a cloud-based platform. Five selected concrete mixes are used to demonstrate the proposed system. The maturity relationships for the selected mixes are developed in the laboratory as per the relevant standards. The early age compressive strengths of the selected concrete mixes are predicted using the established maturity relationship, and the results are found to match well with the actual compressive strengths. The proposed system is found to be effective in the automation of the maturity method that can trigger the implementation of user-friendly Internet/mobile applications for the monitoring of the early age compressive strength of concrete required in the construction industry.

"Wave propagation based monitoring of concrete curing using piezoelectric materials: Review and path forward"

NDT & E International, 2018

https://www.sciencedirect.com/science/article/pii/S0963869517306527

The in-situ strength of concrete is often evaluated by destructive compressive strength tests conducted on cylinders or cube specimens cast alongside the main structure. Various non-destructive testing (NDT) techniques are also available in the industry. In the past decade, the use of piezoelectric based wave propagation (WP) techniques for monitoring the curing process of concrete has attracted considerable interest from researchers in the civil engineering discipline and hence there is a need to summarize the state of knowledge in order for future research efforts to be focused and relevant. This paper therefore presents a review of recent research and development of the abovementioned research area. Existing NDT techniques and piezoelectric based techniques for the monitoring of concrete curing are initially reviewed. Developments associated with the WP technique employing both embedded and surface bonded piezoelectric transducers are then presented. Finally, successful applications of the WP technique are provided. A wide range of parameters adopted by different researchers as concrete strength indicators are also summarized. Theoretical and numerical models available are reviewed, followed by a summary of practical issues related to the application of this technique. Several studies to date have proven the capability of the WP technique in monitoring the curing process of concrete. More rigorous studies are, however, required before a mature technique is developed that can entice commercial interest. Thus, future areas of investigation are identified in the final section. This article is expected to serve as an introduction for researchers interested in venturing into this area and as a valuable summary to inspire existing researchers for further improving the technique.

"Artificial Neural Network-Based Early-Age Concrete Strength Monitoring Using Dynamic Response Signals"
Sensors, 2017
https://www.mdpi.com/1424-8220/17/6/1319

Concrete is one of the most common materials used to construct a variety of civil infrastructures. However, since concrete might be susceptible to brittle fracture, it is essential to confirm the strength of concrete at the early-age stage of the curing process to prevent unexpected collapse. To address this issue, this study proposes a novel method to estimate the early-age strength of concrete, by integrating an artificial neural network algorithm with a dynamic response measurement of the concrete material. The dynamic response signals of the concrete, including both electromechanical impedances and guided ultrasonic waves, are obtained from an embedded piezoelectric sensor module. The cross-correlation coefficient of the electromechanical impedance signals and the amplitude of the guided ultrasonic wave signals are selected to quantify the variation in dynamic responses according to the strength of the concrete. Furthermore, an artificial neural network algorithm is used to verify a relationship between the variation in dynamic response signals and concrete strength. The results of an experimental study confirm that the proposed approach can be effectively applied to estimate the strength of concrete material from the early-age stage of the curing process.

"Piezo-based wireless sensor network for early-age concrete strength monitoring"
Optik, 2016
https://www.sciencedirect.com/science/article/pii/S0030402615018033

Concrete structures play a very important role in human society as they form the very foundation of modern infrastructure. The early-age strength of concrete structure needs to be monitored to guarantee the concrete's structural status and ensure safe construction. The strength of a concrete structure increases as its water content decreases; this process lasts about 4 weeks after it is first cast. Smart aggregates, which are a pre-cast concrete block with embedded piezoceramic material, can be used to monitor this strength development process. One piece of smart aggregate is used as an actuator to generate high frequency vibration waves while the other works in the sensor mode to capture the high frequency vibrations as the wave propagates within the concrete structure. The harmonic amplitude measured by the piezoceramic sensor can then be used to calculate the concrete's strength development. In this letter, the designed wireless sensor network is used to realize the early-age concrete strength monitoring. With the wireless system, concrete strength development can be monitored automatically and remotely. Experiments were carried out and the result verified the use of piezo-based wireless sensor network for early-age concrete strength monitoring.

"Nondestructive Wireless Monitoring of Early-Age Concrete Strength Gain Using an Innovative Electromechanical Impedance Sensing System"
Smart Research Materials, 2013
https://onlinelibrary.wiley.com/doi/full/10.1155/2013/932568

Monitoring the concrete early-age strength gain at any arbitrary time from a few minutes to a few hours after mixing is crucial for operations such as removal of frameworks, prestress, or cracking control. This paper presents the development and evaluation of a potential active wireless USB sensing tool that consists of a miniaturized electromechanical impedance measuring chip and a reusable piezoelectric transducer appropriately installed in a Teflon-based enclosure to monitor the concrete strength development at early ages and initial hydration states. In this study, the changes of the measured electromechanical impedance signatures as obtained by using the proposed sensing system during the whole early-age concrete hydration process are experimentally investigated. It is found that the proposed electromechanical impedance (EMI) sensing system associated with a properly defined statistical index which evaluates the rate of concrete strength development is very sensitive to the strength gain of concrete structures from their earliest stages.

"Design and performance analysis of an embedded wireless sensor for monitoring concrete curing and structural health"
Journal of Civil Structural Health Monitoring, 2011
https://link.springer.com/article/10.1007/s13349-011-0005-9

The monitoring of the properties of concrete introduces many challenges to the design of any non-destructive sensing system. The advance in recent years of wireless technologies has allowed the development of miniaturized sensing systems, which have now reached a stage of development that allows them to be embedded into concrete. This paper describes the design and performance analysis, under replicated building site conditions, of an embeddable wireless sensing node for monitoring concrete curing and structural health.

Wireless sensors with temperature and relative humidity measurement capabilities were designed with onboard communication using the 433 MHz ISM band and embedded into concrete. Testing, which replicated on-site conditions, was carried out on the sensors to determine what the effect of the concrete itself, the steel reinforcement, and steel backed formwork had on the transmission of data. The transmission distance and reliability of receiving data was quantified. Test results confirm that it is possible to deploy an embedded sensor system and transmit live data from the embedded sensor to a data acquisition system located outside the concrete. Preliminary results show that steel backed formwork reduces the transmission distance of the sensors to 3.5 m from 5 m without formwork. Analysis of the data from the sensor showed that, while temperature readings were reliable, the method of measuring relative humidity, using a shielded humidity sensor, may not be suitable for use over the full lifetime of the structure. Accordingly, the electromechanical impedance (EMI) method was enhanced to allow it be used in an embedded system incorporating the AD5933 impedance chip. The EMI method has been successfully applied to monitor the strength development and deterioration of concrete but limited investigation has been carried out into advancing the method for deployment in embedded sensing systems. Analysis of the strength development of freshly mixed concrete and the effects of loading on the response of the sensor show that it is possible to monitor both the strength development and subsequent deterioration of concrete by monitoring the reactance antiresonant frequency shift and peak resistance of a piezoelectric material embedded into concrete. Analysis of the reactance antiresonant frequency shift showed that the technique successfully monitored the compressive strength development of the concrete structure, while monitoring the reactance antiresonant frequency shift in conjunction with the resistance peak provided important information on the condition of the concrete under loading conditions. This is believed to be the first time that the EMI method for monitoring concrete curing and structural health has been demonstrated for use in an embedded wireless sensing system.

“Concrete early-age strength monitoring using embedded piezoelectric transducers”
IOP Publishing, 2006
https://iopscience.iop.org/article/10.1088/0964-1726/15/6/038/meta

At early ages of concrete structures, strength monitoring is important to determine the structures’ readiness for service. Piezoelectric-based strength monitoring methods provide an innovative experimental approach to conduct concrete strength monitoring at early ages. In this paper, piezoelectric transducers in the form of ‘smart aggregates’ are embedded into the concrete specimen during casting. Piezoceramic materials can be used as actuators to generate high frequency vibrating waves, which propagate within concrete structures; meanwhile, they can also be used as sensors to detect the waves. The smart aggregate is a one cubic inch, pre-cast concrete block with a wired, embedded PZT (lead zirconate titanate, a type of piezoceramic) patch. The strength development of concrete structures is monitored by observing the development of harmonic response amplitude from the embedded piezoelectric sensor at early ages. From experimental results, the amplitude of the harmonic response decreases with increasing concrete strength. The concrete strength increases at a fast rate during the first few days and at a decreasing rate after the first week. Concordantly, the amplitude of the harmonic response from the piezoelectric sensor drops rapidly for the first week and continues to drop slowly as hydration proceeds, matching the development of the concrete strength at early ages. Concrete is heterogeneous and anisotropic, which makes it difficult to analyze mathematically. Fuzzy logic has the advantage of conducting analysis without requiring a mathematical model. In this paper, a fuzzy logic system is trained to correlate the harmonic amplitude with the concrete strength based on the experimental data. The experimental results show that the concrete strength estimated by the trained fuzzy correlation system matches the experimental strength data. The proposed piezoelectric-based monitoring method has the potential to be applied to strength monitoring of concrete structures at early ages.